

EXTRACTING SPATIAL INFORMATION FROM LARGE APERTURE EXPOSURES OF DIFFUSE SOURCES

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ABSTRACT

The spatial properties of large aperture exposures of diffuse emission can be used both to investigate spatial variations in the emission and to filter out camera noise in exposures of weak emission sources. Spatial imaging can be accomplished both parallel and perpendicular to dispersion with a resolution of 5-6 arc sec, and a narrow median filter running perpendicular to dispersion across a diffuse image selectively filters out point source features, such as reseau marks and fast particle hits. Spatial information derived from observations of solar system objects will be presented.

INTRODUCTION

Since the IUE telescope has an image quality of 3 arc sec and a total instrumental resolution of 5-6 arc sec, it is possible to accomplish spatial imaging of diffuse sources within the 10 x 23 arc sec entrance aperture in a single exposure. Spatial asymmetries have been observed in planetary spectra in the directions both parallel and perpendicular to the dispersion line, and a relative sensitivity calibration of the instrumental response along the major axis of the aperture (perpendicular to dispersion) at H Ly α (1216 Å) has been obtained from exposures of diffuse geocoronal emission. It is seen that diffuse emission produces an image on the camera which is ~ 20 arc sec full width at half maximum (FWHM) in the direction perpendicular to dispersion; by contrast, noise features such as radiation-induced spikes and reseau marks are generally not greater than 6 arc sec FWHM. Running a narrow median filter across the data in this direction readily discriminates between these noise features and the diffuse emission. Details of the data reduction procedures which we have developed both for spatial imaging within the large aperture and for noise filtering in images of diffuse emission will be presented here, along with sample data showing:

- i) spatial imaging in observations of geocoronal emission and Jovian aurora, and
- ii) noise filtering in spectra of weak emissions from the Io torus.

SPATIAL IMAGING

Spatial imaging in exposures using the large entrance aperture with the SWP camera requires knowledge of the relative sensitivity of the instrument in the exposed region of the camera face. This is most easily accomplished by taking an exposure of a uniform diffuse source; at 1216 Å such a source exists in the geocoronal H Ly α emission. This section gives the result of adding 6 exposures of geocoronal Ly α background to obtain the relative sensitivity of the SWP camera along the major axis of the large aperture, i.e. perpendicular to dispersion.

This one-dimensional spatial imaging has been accomplished by integrating the flux with respect to wavelength around 1216 \AA in each of the line-by-line spatially resolved spectra in the vicinity of the large aperture. The zero flux level was determined by an average of the flux level on either side of the Ly α emission. The estimated position of these lines is shown on the righthand side of Figure 1 (line 9 is the central dispersion line). The line and order numbers increase toward the center of the camera face.

The circles plotted on the left-hand side of Fig. 1 represent the sum of exposures SWP 4009-4014 (taken 24 January 1979), adding the wavelength-integrated fluxes at 1216 \AA individually for each line number. These summed fluxes are listed in Table 1 in units of IUE flux numbers, and in arbitrary units which are normalized to one for the central dispersion line. Subsequent images of diffuse emission may be divided line-by-line by these numbers to correct for relative response in the aperture. A second sum of geocoronal exposures taken on 12 March 1980 showed the same profile to within 5% for the individual points, indicating no significant changes in the relative response of the camera over one year of operation. The X's plotted on the same graph show the peak flux in each line near 1650 \AA in a short exposure of a stellar source, indicating an instrumental spatial FWHM of about 6 arc sec. For comparison, Koorneef and de Boer (IUE Newsletter no. 5) obtained 5.1 arc sec FWHM in a more accurate determination of the point source response. Given the size of the large aperture (10.3×23.0 arc sec) three point sources could be resolved in the length of the aperture, and some imaging is possible along the dispersion direction.

It should be pointed out that thermal shifts in the spacecraft may move the large aperture image slightly on the detector face, and the central dispersion line may be moved from side to side in the IUE data reduction procedure. Care should be taken to determine accurately which spatially-resolved spectrum corresponds to the center of the large aperture image before this calibration is applied. In addition, this calibration is strictly accurate only at 1216 \AA .

As an example, Fig. 2 shows a 3-dimensional spectral-spatial image of IUE exposure SWP 5309 of the north polar region of Jupiter, taken with the large entrance aperture on 19 May 1979. The dispersion direction, along the X-axis, is marked in \AA , the Y-axis represents flux, and the Z-axis gives spatial imaging along a line which is roughly north-south. H_2 Lyman band emissions are visible from the north pole at around 1570 \AA and at 1608 \AA , and to a lesser extent around 1250 \AA .

NOISE FILTERING

In a series of long (7-8 hours) exposures of the Io plasma torus taken with the large aperture and the SWP camera, noise features were found to be comparable in intensity to the weak observed emission lines. This section describes three procedures employed in the reduction of these data to preferentially filter out the noise features:

- 1) Limiting the width of the artificial slit used in the extraction of the gross spectrum

- ii) Running a 7-point median filter on the data perpendicular to dispersion
- iii) Adding exposures

Methods (i) and (ii) capitalize on the fact that an emission line from an extended source is much broader perpendicular to dispersion than the noise features, which tend to appear as point sources above the pedestal level. Noise spikes are produced randomly by fast particle hits on the detector camera face; in addition, some noise features recur at the same position on the camera, presumably caused by chemical imbalance in the camera phosphor. At the curved edges of the large aperture the flux from a uniform diffuse source decreases (see preceding article); including only the central portion of the aperture in the gross spectrum thus improves the signal-to-noise ratio, and also bypasses a couple of reseau marks. This was accomplished by adding the central 7 orders of the 55-line spatially resolved spectra (e.g. setting $H = 7$), and then normalizing the background flux accordingly.

To compensate for throwing away the flux from the curved edges of the aperture the fluxes are multiplied by the appropriate geometric factor (1.64): this is accurate only if the diffuse source is uniform in intensity.

A narrow median filter passed over the data perpendicular to the dispersion line would have the effect of erasing only features which are narrow compared to the size of the filter, i.e. a high-frequency filter. A 7-point median filter (14-15 arc sec) was found to distinguish well between point sources (FWHM of 5-6 arc sec) and diffuse emission (FWHM of 18-20 arc sec). This filter was run using the spatially-resolved spectra, so that the separation of "points" perpendicular to dispersion was 2.1 arc sec. The flux in a given order at a given wavelength was determined by the median of the fluxes at the same wavelength of 7 spatial orders, centered on the given order. The filter was thus a "running median". Fig. 3 shows the result of a 7-point running median on a sample profile which combines diffuse emission (taken from the geocoronal Ly α profile from the preceding article) and a point source noise spike (FWHM = 6 arc sec). The dashed line is the "before" picture, the solid line "after" the filter. The filter completely wipes out the noise spike, but may also truncate the diffuse emission by a few percent.

The well-known technique of adding spectra to improve signal-to-noise was applied to 3 spectra of comparable duration, after each of these spectra had been compiled using the previous two techniques. This spectrum, labelled "Sum", is shown in Fig. 4 along with one of the three separate spectra, as compiled under the standard IUE extended-source reduction. Although these techniques have been applied only to images of a diffuse source thus far, they should work equally well on trailed spectra of point sources.

TABLE 1

<u>Line</u>	<u>IUE</u>	<u>FN</u>	<u>($\times 10^3$) $\times \text{\AA}$</u>	<u>Relative Sensitivity</u>
3			21	.04
4			175	.33
5			368	.69
6			465	.87
7			488	.91
8			516	.97
9			534	1.00
10			547	1.02
11			574	1.07
12			530	.99
13			438	.82
14			243	.45
15			94	.18

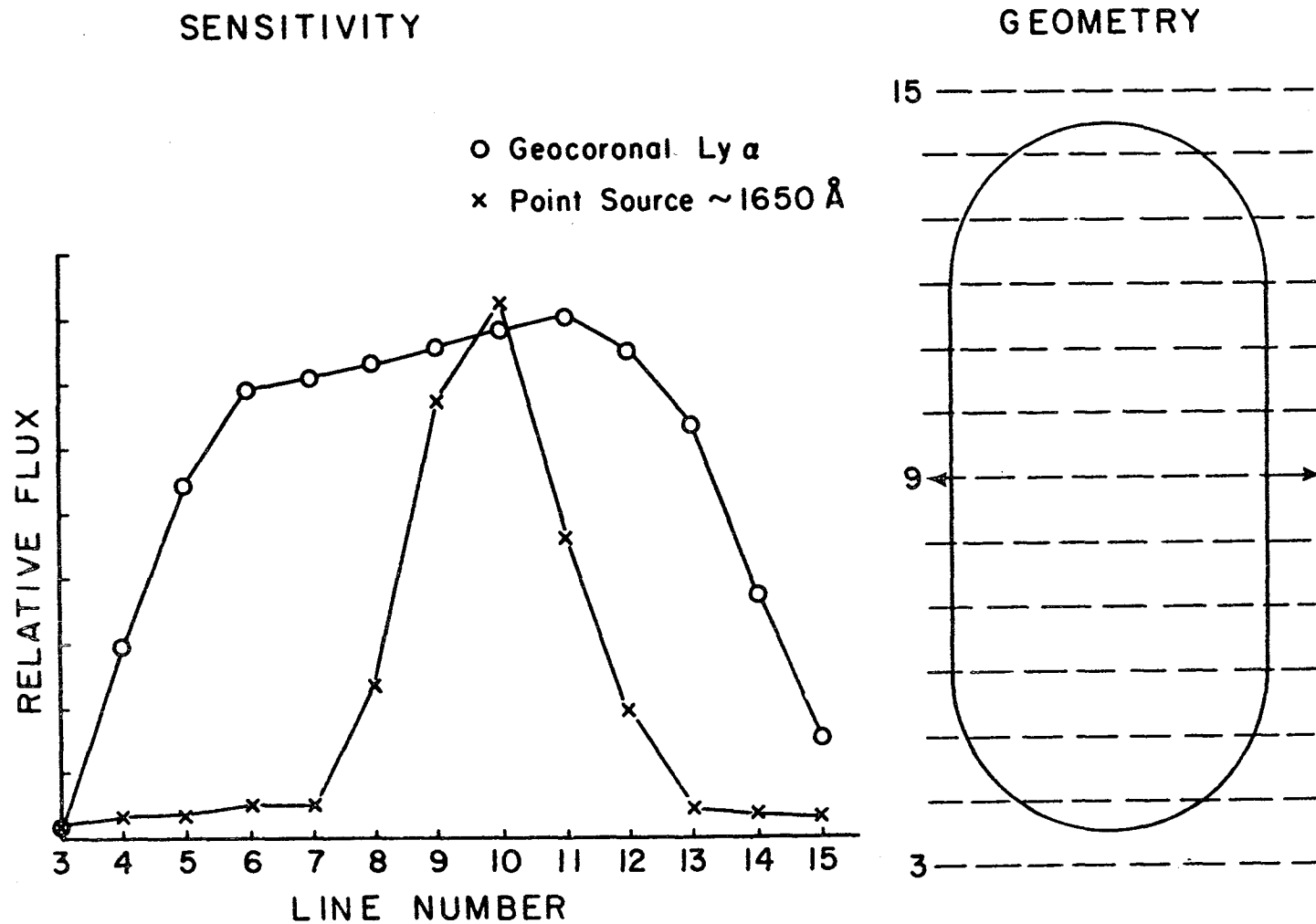


Figure 1

SWP 5309
5/19/79

JUPITER NORTH POLE

792

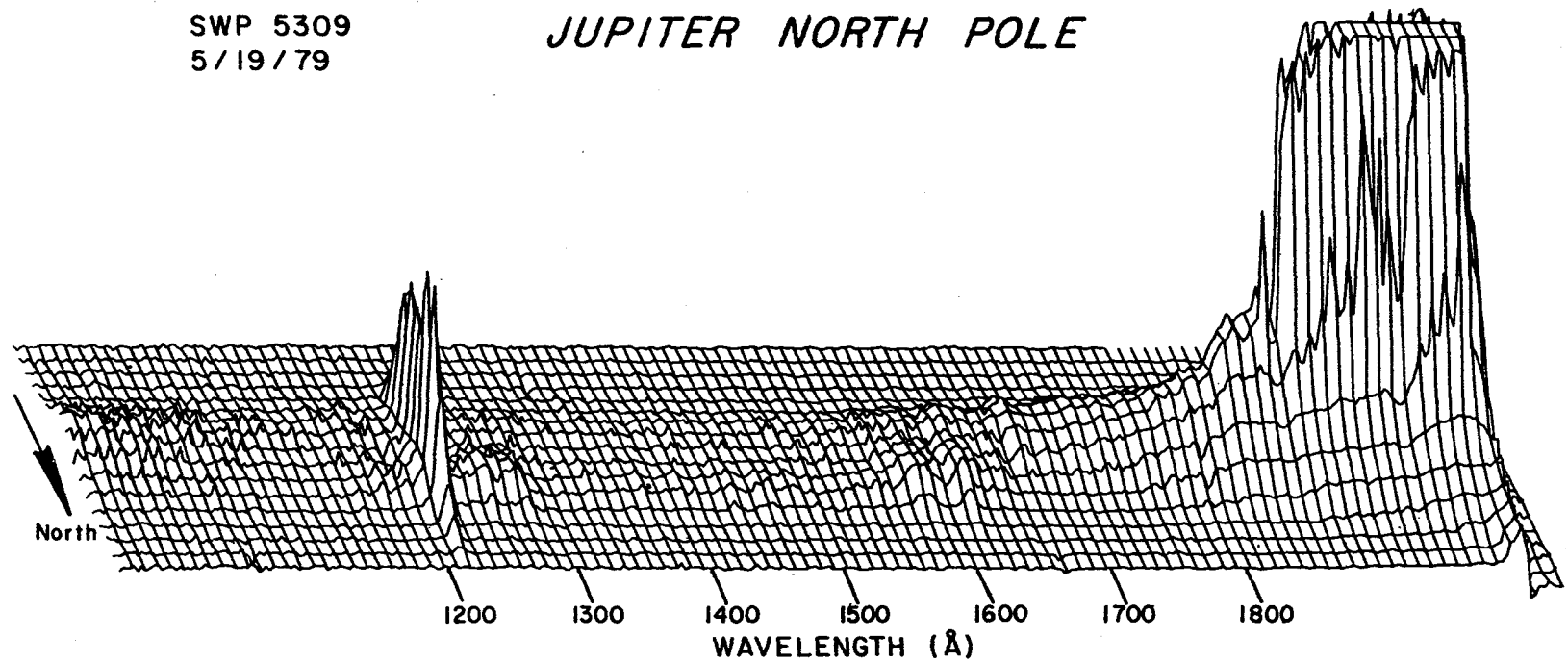


Figure 2

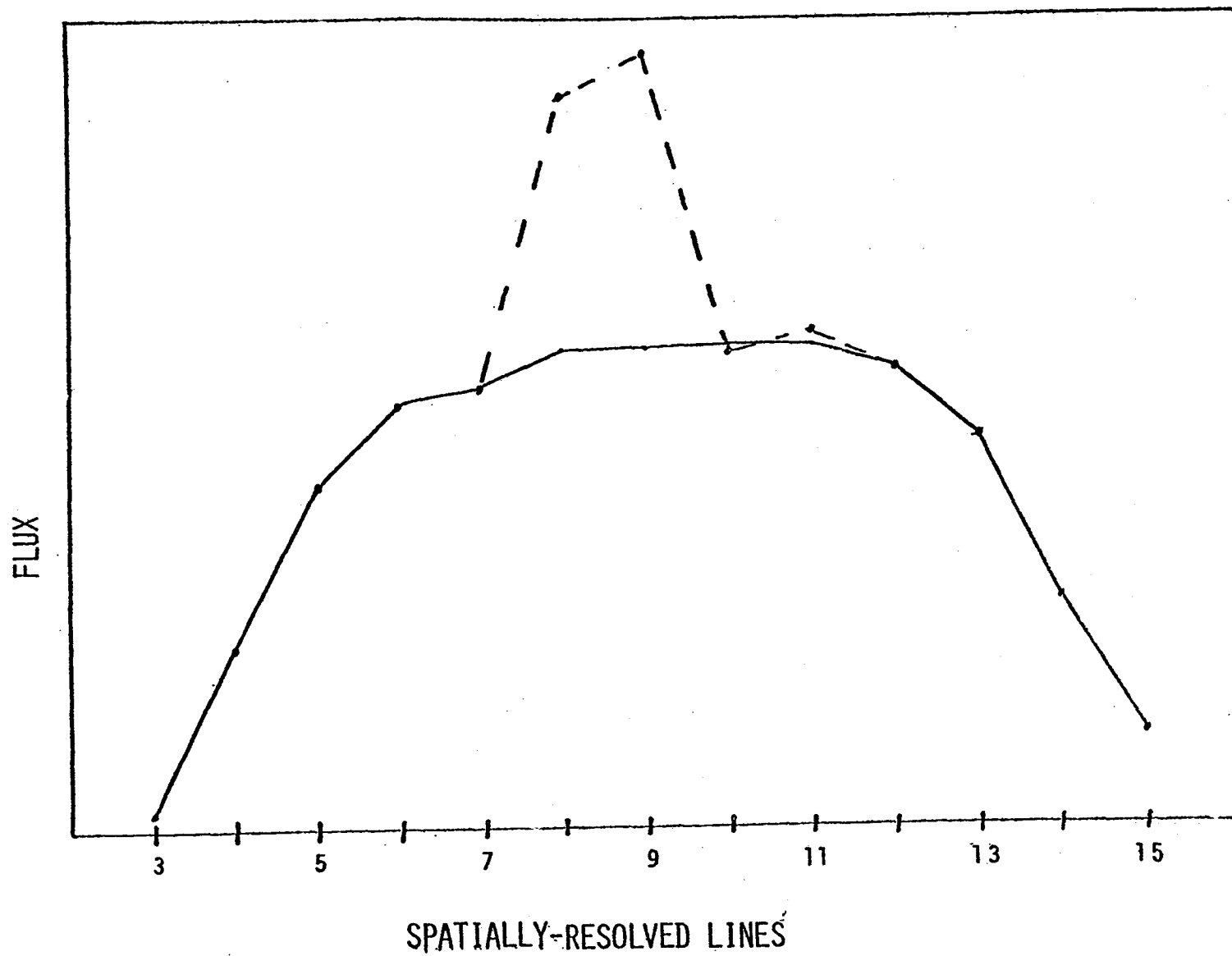


Figure 3

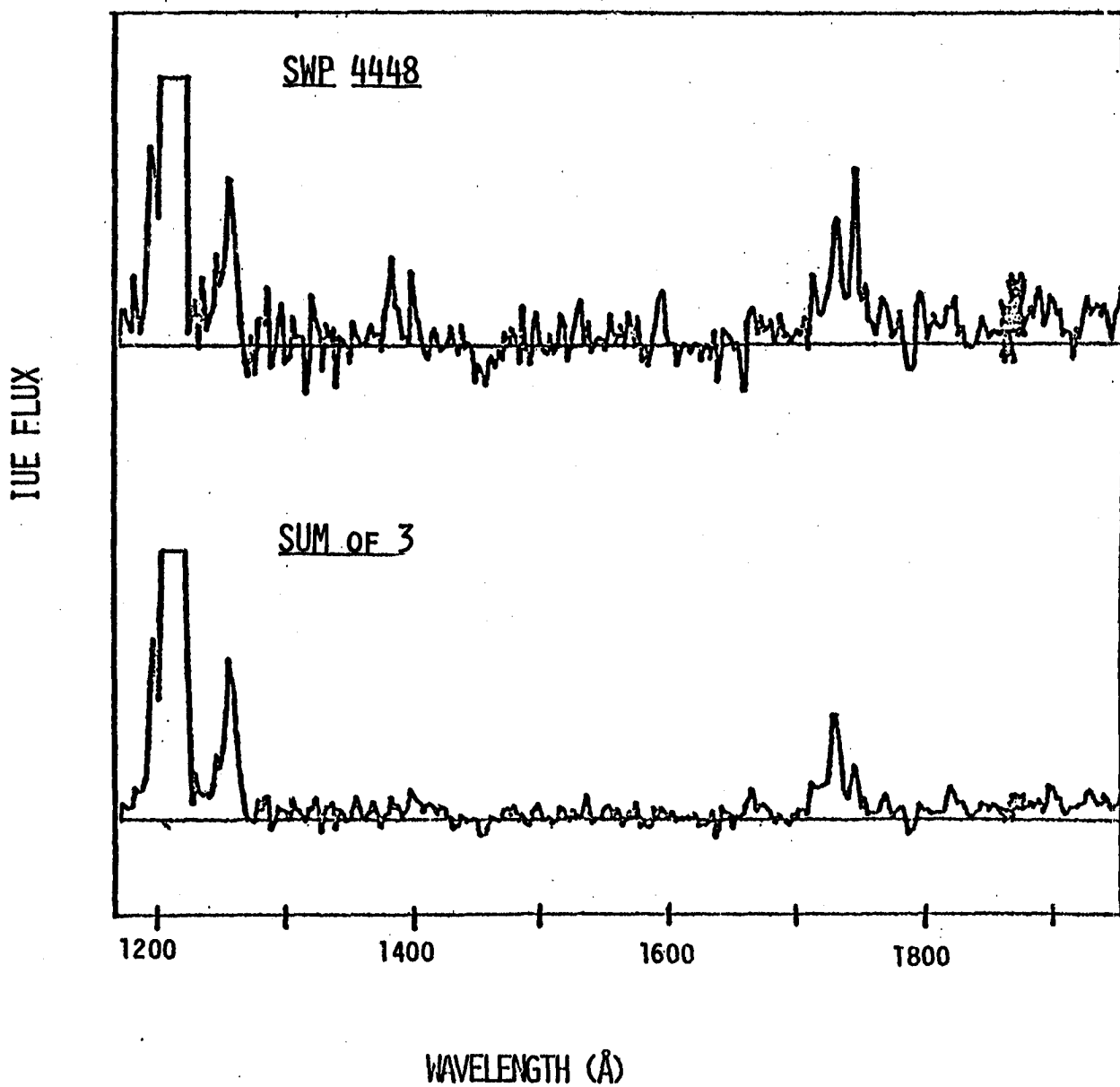


Figure 4